CHAPTER 3

GEOMETRIC DESIGN FOR ROADS AND STREETS

3-1. Cross-section elements.

a. Pavement.

(1) Type surface. Pavement type is seldom an important factor in geometric design; however, the ability of a pavement surface to retain its shape and dimensions, its cross-section, and the possible effect of pavement surface on driver behavior should be considered in geometric design.

(2) Normal cross slope. Selection of proper cross slope depends upon speed-curvature relations, vehicle characteristics, curb requirements, and general weather conditions. Cross slope for sharp curves (superelevation) is discussed in AASHTO GD-2. Cross slope on tangents and flat curves are shown in tables 1-1 and 1-2. Where two or more lanes are inclined in the same direction on Class B roads and streets, each successive lane outward from the crown line should have an increased cross slope. The lane adjacent to the crown line should have the minimum cross slope shown in tables 1-1 and 1-2 and the cross slope of each successive lane should be increased 1/16 in/ft. Where pavements are designed with barrier curbs, it is recommended that a minimum cross slope of 3/16 in/ft be used on Class B roads and streets and that a minimum cross slope of 1/4 in/ft be used on Class D and E roads and streets.

b. Lane width. The number and width of traffic lanes shown in tables 1-1 and 1-2 are the minimum considered adequate to accommodate the indicated design hourly volume when the traffic is composed principally of wheeled vehicles whose overall widths are 8.5 feet or less. Wider traffic lanes are required when the traffic is composed of a significant percentage of vehicles whose overall widths are greater than 8.5 feet. In general, the lane width will be increased by the excess width of the largest over-sized vehicle (vehicle width minus 8.5 feet to the nearest higher even foot) where such traffic is anticipated.

3-2. Curbs, combination curbs, and gutters. Curbs, combination curbs and gutters, and paved gutters with attendant storm drainage facilities will not be considered during a mobilization situation unless they are determined to be absolutely necessary or conditions would allow their construction. The road or street design will account for the "no curb" feature and provide for drainage and erosion control accordingly.

a. Curb construction. In built-up areas, curbs, combination curbs and gutters, and paved gutters with attendant underground storm drainage systems will be provided when necessary along streets and in open storage areas as required to aid in the collection and disposal of surface runoff including snowmelt, to control erosion, to confine traffic, or as required in the extension of existing similar facilities. In open areas, combination curbs and gutters will not be provided along roads except where necessary on steep grades to control drainage and prevent erosion of shoulders and fill slopes. Where such facilities are required, they should be located outside the edges of traffic lanes and should be either of the mountable type with suitable outlets and attendant drainpipes or paved gutters with shallow channels extending across the road shoulders and down the fill slopes.

b. Classification and types. Curbs are classified as barrier or mountable according to their intended use. Barrier curbs are designed to prevent or at least discourage vehicles from running off the pavement and therefore have a steeply sloping face at least 6 inches high. Mountable curbs are designed to allow a vehicle to pass over the curb without damage to the vehicle, and have a flat sloping face 3 to 4 inches high. For construction purposes, curbs are usually designated as "combined curb and gutter" and "integral curb and gutter." For Army installations curbs are divided into four types for convenience of reference: Type I is a combined gutter section and barrier curb; Type II is a combined gutter section and mountable curb; Type III is a combined gutter section and offset barrier curb; and Type IV is a barrier curb integral with pavement slab. Curbs should be placed on undisturbed subgrade or subgrade compacted to the same density as subgrade of adjacent road.

c. Location in regard to lane width.

(1) Type I, III, or IV (barrier curbs). It is necessary to offset barrier curbs a sufficient distance from the edge of the nearest traffic lane to prevent reduction in capacity. Curb offset and traffic lane width for classified roads and streets designed with barrier curbs are shown in tables 1-1 and 1-2.

(2) Type II curbs. Mountable curbs cause very little, if any, lateral displacement of traffic adjacent to these curbs; therefore, it is acceptable to locate Type II curbs at the edge of a traffic or parking lane.

3-3. Road and street appendages.

a. Shoulders.

(1) Width. Shoulder widths should be as stated in tables 1-1 and 1-2.

(2) Shoulders for roads. Roads in rural areas are normally designed without curbs and require full width shoulders to accommodate

high traffic volumes. Geometric design criteria for shoulders on roads are presented in table 1-1.

(3) Shoulders for streets. As a general rule, streets in cities are designed with some type of barrier curb and do not require shoulders except where needed for lateral support of the pavement and curb structure. Where lateral support is required, the shoulder should be at least 4 feet in width where feasible. In other sections within built-up areas, where desirable to design streets without barrier curbs, geometric design criteria are presented in table 1-2.

b. Medians.

(1) Uses. Where traffic volume requires construction of multilane highways, opposing traffic should be separated by medians. Medians should be highly visible both day and night, and there should be a definite color contrast between median and traffic lane paving. The absolute minimum width for a median is 4 feet with a desirable minimum width of 14 feet.

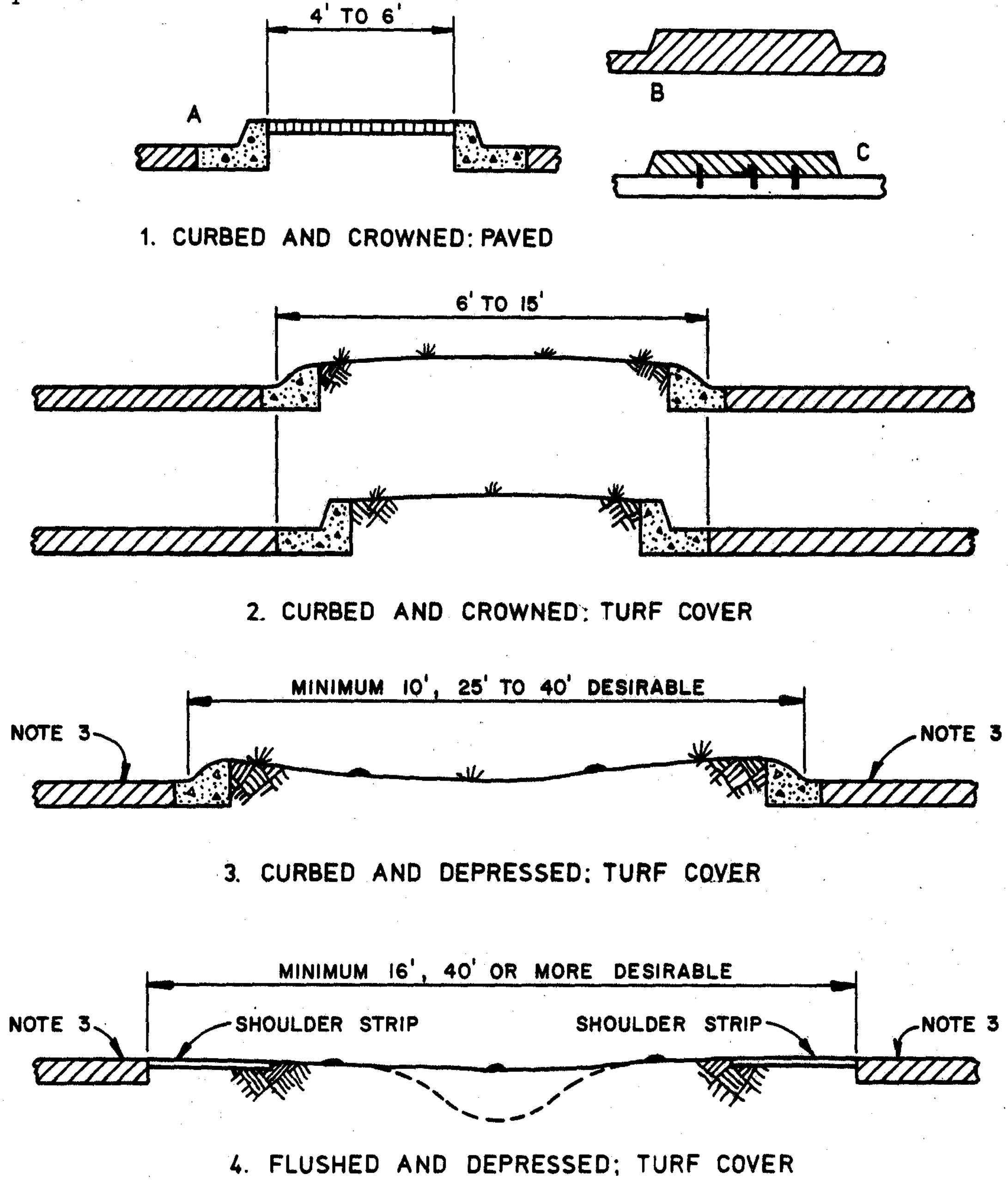
(2) Types. Cross sections of medians are illustrated in figure 3-1. It is not necessary that medians be of uniform width throughout the length of divided highways.

(3) Curbs. All design criteria relative to curbs presented herein are applicable to median curbs.

c. Guardrails and guideposts.

(1) Uses. For safety and guidance of traffic, guideposts should be provided at all locations along roadways where drivers may become confused, particularly at night, as to the direction of the roadway; along roadways subject to periodic flooding; along roadways where fog exists for long periods of time; and where driving off the roadway is prohibited for reasons other than safety. Guardrails are normally required at locations where vehicles accidentally leaving the roadway might be damaged, resulting in injury to occupants. Guardrails or guideposts should conform to local highway department criteria.

(2) Design criteria. Guardrails or guideposts are not normally required where the front side slopes are 4:1 or flatter. Design criteria for determining where guardrails or guideposts are required is shown by figure 3-2. The ordinate of this figure, designated "Height of Cut or Fill in Feet," is used in this manual to refer to the vertical distance between the outside (intersection of shoulder and front slope planes) edge of the shoulder and the toe of the front slope in cuts and on fills, or between the toe and top of back slope in cuts.



NOTES:

1. Curbs and paved median may be monolithic as in 1-B or may be surface-mounted on monolithic pavement as in 1-C. If surface-mounted, the curb-and-median slab must be anchored or bonded to the pavement (1-C).

2. All medians less than 10 feet wide should be designed with barrier curbs. If vegetation is to be maintained on median, or if snow removal will be required, the minimum width of median should be 10 feet. Separating guardrails will be installed in medians if justified by traffic conditions.

3. Where depressed medians are used for 4-lane highways, opposing lanes are to utilize standard Class B 2-lane roads design.

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FIGURE 3-1. CROSS SECTIONS OF GENERAL TYPES OF MEDIANS

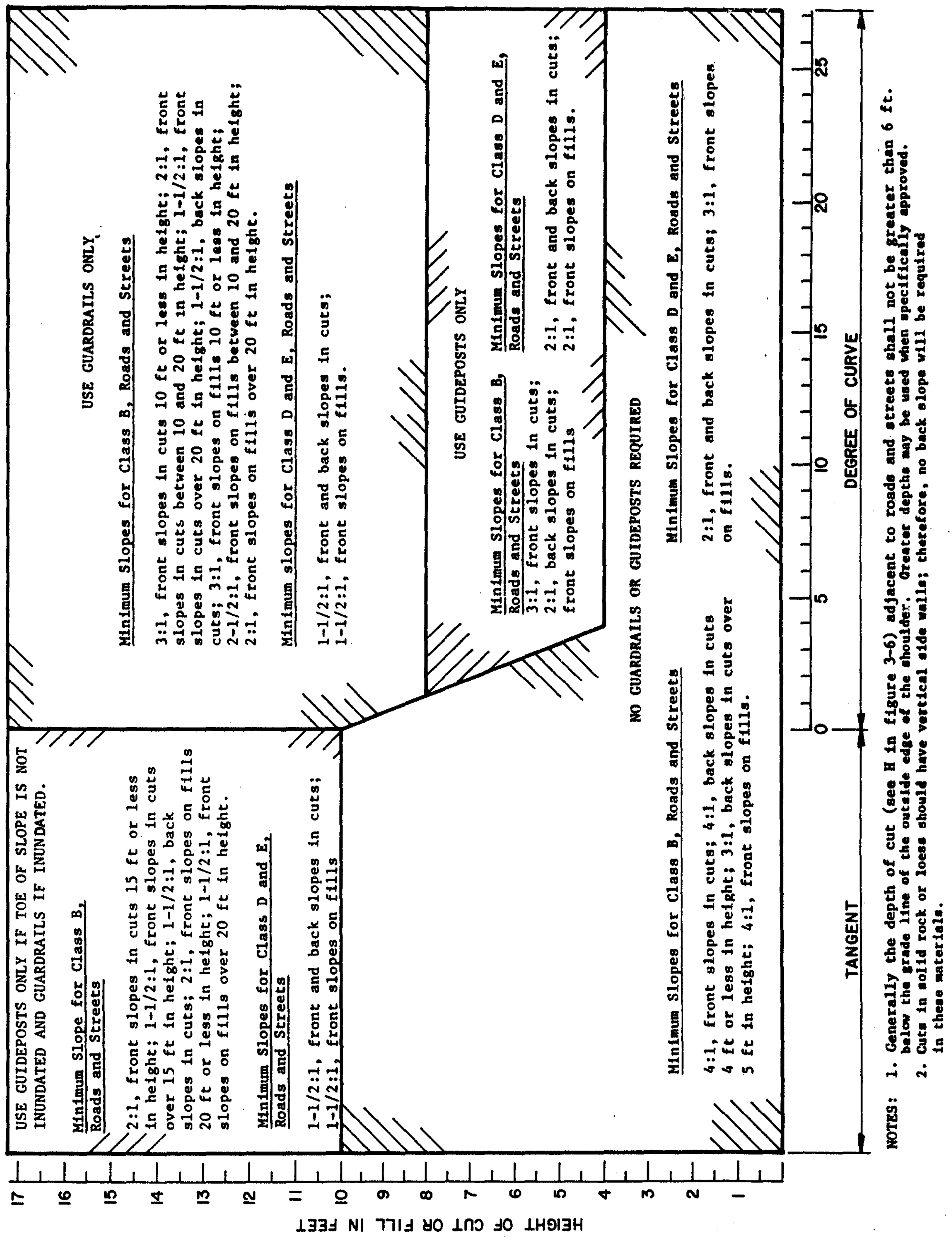

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FIGURE 3-2. DESIGN CRITERIA; GUARDRAILS, GUIDE POSTS, AND EARTH SLOPES

(3) Location with respect to edge of pavement. Guardrails or guideposts should be located at a constant offset from the edge of a pavement outside the limits of the usable shoulder and with an elevation of the base between 4 inches and 9 inches below the edge of the lane pavement. Shoulder widths shown in tables 1-1 and 1-2 will be widened 2 feet to provide space for installation of guardrails or guideposts. Guardrails or alinement of guideposts should be flared outward and, if required, buried on the traffic approach end and tapered in at narrow structures to meet curb lines.

(4) Marking. Guardrails and guideposts must be highly visible, particularly at night. All guardrails and guideposts should be marked or painted in accordance with AASHTO safety requirements.

d. Earth slopes. In determining inclination of side slopes, proper consideration should be given to drainage, maintenance, erosion, and stability. It may be difficult to control erosion of some soils on steep slopes (4:1 or steeper), and it may be impossible to control erosion or maintain vegetation cover on slopes steeper than 2:1. If maintenance is to be accomplished without special equipment, side slopes should not be steeper than 3:1. It is essential that side slopes along highways be flat enough to assure stability under all normal conditions. Design criteria for selecting earth slopes is presented in combination with design policy for establishing need for guardrails and guideposts in figure 3-2.

e. Bridge clearance. Requirements affecting highway safety are found in AASHTO HB-12.

(1) Horizontal. The minimum horizontal distance between curbs on bridges should be equal to the width of the approaching roadway including traffic lanes, parking lanes, full width of shoulders, and medians (on divided highways). When the cost of parapets and railings is less than the cost of decking the median area, traffic lanes for traffic in opposing directions will be on separate structures. It is usually more economical to pave over the median area on bridges with a median width less than about 15 feet.

(2) Vertical. The minimum vertical clearance will be at least 14 feet over all traffic lanes, parking lanes, and shoulders.

3-4. Sight distance. The length of roadway visible ahead of a vehicle along a highway is termed "sight distance." Sight distance is divided into two categories: stopping sight distance and passing sight distance. Minimum stopping and passing sight distances are shown in tables 1-1 and 1-2. Effort should be made to provide sight distances greater than those shown.

a. Stopping sight distance. On single-lane roads, the stopping sight distance must be adequate to permit approaching vehicles each to stop. Horizontal curve sight distance will be critical and will be twice that required for a two or more, lane highway.

b. Passing sight distance. Passing sight distance should be provided as frequently as possible along two-lane, two-way roads, and a length equal to or greater than the minimum values shown in table 1-1 should be provided. The minimum passing sight distances in table 1-1 provide safe distances for a single isolated vehicle traveling at design speed to pass a vehicle going 10 mph less than design speed. Sight distances and safe passing sections should be shown on all construction and improvement plans to aid in proper marking and sign placement.

3-5. Horizontal alinement.

a. General. Where changes in horizontal alinement are necessary, horizontal curves should be used to affect gradual change between tangents. In all cases; consideration should be given to the use of the flattest curvature practicable under existing conditions. Adequate design of horizontal curves depends upon establishment of the proper relations between design speed and maximum degree of curvature (or minimum radius) and their relation to superelevation. The maximum degree of curvature is a limiting value for a given design speed and varies with the rate of superelevation and side friction factors.

b. Maximum curvature.

(1) Roads. Desirable and absolute values for use in design of horizontal curves on superelevated roads are shown in table 1-1. The absolute maximum curvature for roads without superelevation is the same as shown for streets with normal crown sections in table 1-2.

(2) Streets. Absolute maximum values for degree of curvature on streets in built-up areas are shown in table 1-2. Absolute maximum values are given for streets with normal crown sections (no superelevation) and with superelevated sections.

c. Superelevation. A practical superelevation rate together with a safe side friction factor determines maximum curvature. Superelevation rate and side friction factors depend upon speed, frequency and amount of precipitation and type of area, i.e., built-up or open. Superelevation rates will be determined in accordance with AASHTO GD-2.

d. Widening of roads and streets.

(1) Pavements on roads and streets will be widened to provide operating conditions on curves comparable to those on tangents. Widening is necessary on certain highway curves because long vehicles occupy greater width and the rear wheels generally track inside the

front wheels. The added width of pavement necessary can be computed by geometry for any combination of curvature and wheel base. Generally, widening is not required on modern highways with 12-foot lanes and hightype alinement, but for some combinations of speed, curvature, and width, it may be necessary to widen these highways also. The amount of widening required on horizontal curves on roads is shown in table 3-1.

(2) This is the widening normally required for off-tracking and may not provide clearance where sight is restricted. The additional width should be added to the inside of the curve, starting with zero at the TS (tangent-spiral), attain the maximum at the SC (spiral-curve), and diminishing from the maximum at the CS (curve spiral) to zero at the ST (spiral-tangent) as shown in figure 3-3. Increased sight distance may be provided by additional widening or by removal of sight obstructions. The latter is normally recommended because it is generally more economical. Figure 3-4 shows the relation between sight distance along the center line of the inside lane on horizontal curves and the distance to sight obstructions located inside these curves. The clear sight distance along the center line of the inside lane on horizontal curves should equal the minimum stopping sight distance shown in table 1-1 for the design speed.

3-6. Vertical alinement.

a. Grade. Design of vertical alinement involves the establishment of longitudinal grade or slope for roads, streets, and highways. The key considerations for determining grades are speed reduction for maximum grade and drainage for minimum grade.

(1) Determining maximum grade. The maximum allowable grade is dependent on the length the grade is sustained. The critical length of grade is the distance a design vehicle with a 40,000 pound gross weight and a 100-hp engine can travel up a designated grade before speed is reduced below an acceptable value (usually 30 mph). Critical lengths for grades are shown in tables 1-1 and 1-2. If a grade exceeds critical length, highway capacity is reduced unless a climbing lane is added for heavy vehicles.

(2) Determining minimum grade. Tables 1-1 and 1-2 give minimum grades which are adequate for proper drainage.

b. Curves. Generally, vertical curves should be provided at all points on roads or streets where there is a change in longitudinal grade. The major control for safe vehicle operation on vertical curves is sight distance, and the sight distance should be as long as possible or economically feasible. Minimum sight distance required for safety must be provided in all cases. Vertical curves may be any one of the types of simple parabolic curves shown in figure 3-5. There are three length categories for vertical curves: maximum, length required for safety, and minimum. All vertical curves should be as long as

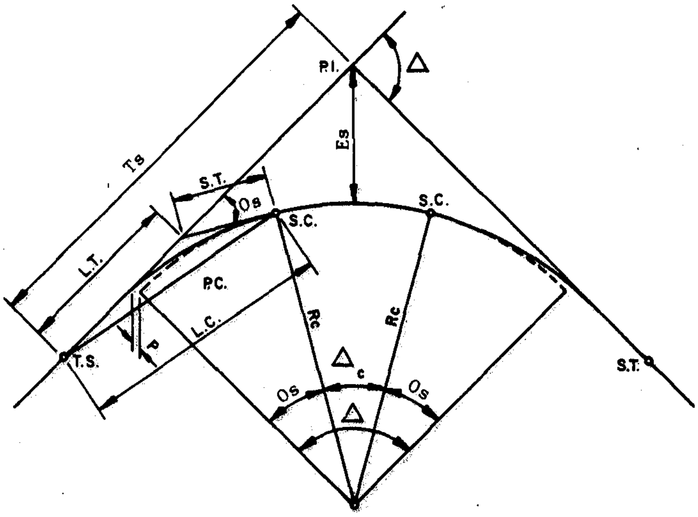
Table 3-1. Calculated and Design Values for Pavement Widening on Roads and Streets Within Army Installations 2-Lane Pavements, One-Way or Two-Way

Widening, in Feet, for 2-Lane Pavements on Curves for Width of Pavement on Tangent of:

Degree of Curve	24 feet Design speed, mph						22 feet Design speed, mph					20 feet Design speed, mph			
	30	40	50	60	70	80	30	40	50	60	70	30	40	50	60
1	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5	1.0	1.0	1.5	1.5	1.5	2.0
2	0.0	0.0	0.0	0.5	0.5	0.5	1.0	1.0	1.0	1.5	1.5	2.0	2.0	2.0	2.5
3	0.0	0.0	0.5	0.5	1.0	1.0	1.0	1.0	1.5	1.5	2.0	2.0	2.0	2.5	2.5
4	0.0	0.5	0.5	1.0	1.0		1.0	1.5	1.5	2.0	2.0	2.0	2.5	2.5	3.0
5	0.5	0.5	1.0	1.0			1.5	1.5	2.0	2.0		2.5	2.5	3.0	3.0
6	0.5	1.0	1.0	1.5			1.5	2.0	2.0	2.5		2.5	3.0	3.0	3.5
7	0.5	1.0	1.5				1.5	2.0	2.5			2.5	3.0	3.5	
8	1.0	1.0	1.5				2.0	2.0	2.5			3.0	3.0	3.5	
9	1.0	1.5	2.0				2.0	2.5	3.0			3.0	3.5	4.0	
10-11	1.0	1.5					2.0	2.5				3.0	3.5		
12-14.5	1.5	2.0					2.5	3.0				3.5	4.0		
15-18	2.0						3.0					4.0			
19-21	2.5						3.5					4.5			
22-25	3.0						4.0					5.0			
26-26.5	3.5						4.5					5.5			

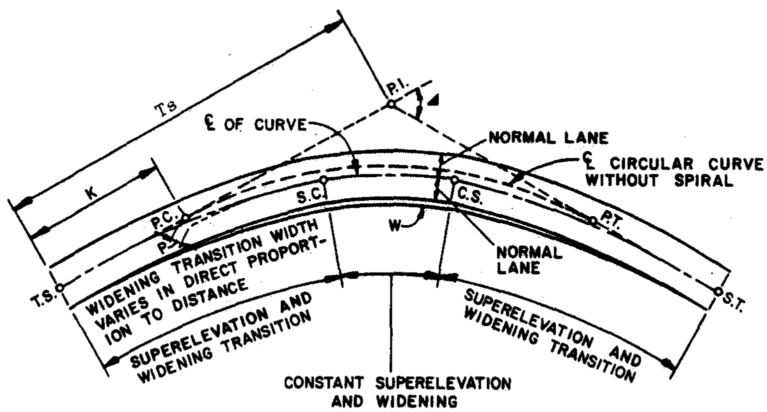
NOTES: Values less than 2.0 may be disregarded.
3-lane pavements: multiply above values by 1.5.
4-lane pavements: multiply above values by 2.
Where semitrailers are significant, increase tabular values of widening by 0.5 for curves of 10 to 16 degrees, and by 1.0 for curves 17 degrees and sharper.

HORIZONTAL CURVES WITH TRANSITION SPIRALS — BOTH ENDS



<u>TRANSITION SYMBOLS</u>

- P.I. -Point of intersection of main tangents.
- T.S. -Common point of tangent and spiral.
- &S.T. Spiral and tangent.
- S.C. -Spiral curve, common point of spiral and circular curve of near transition.
- C.S. -Curve spiral, common point of circular curve and spiral of far transition.
- Rc -Radius of circular curve.
- Ls -Length of spiral between T.S. and S.C.
- Ts -Tangent distance P.I. to T.S. or S.T, or Tangent distance of the complete curve.
- L.C. -Straight Line Chord distance T.S. to S.C.
- K -Distance from T.S. to point on tangent opposite the P.C. of the circular curve produced.
- Es -External distance P.I. to center of circular curve portion.
- L.T. -Long tangent distance of spiral only.
- S.T. -Short tangent distance of spiral only.
- P -Offset distance from the tangent of P.C. of circular curve produced.
- Δ -Intersection angle between tangents of entire curve.
- Δ c -Intersection angle between tangents at S.C. and at the C.S. or the central angle of the circular curve portion of the curve.
- Os -Intersection angle between the tangent of the complete curve and the tangent at the S.C., The spiral angle.
- W -Widening



To locate spiral transition, use tables as given in Transition Curves for Highways, (See appendix A, Government Depository Libraries)

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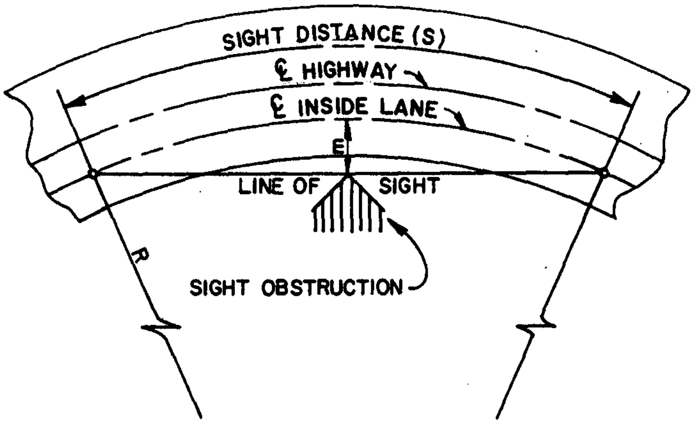
FIGURE 3-3. METHOD OF LAYOUT OF WIDENING AND SUPERELEVATION OF SPIRAL LANES

$$m = \frac{5730}{D} \text{ VERS } \frac{50}{200}$$

$$\text{Also } m = R\left(\text{VERS } \frac{2865S}{R}\right)$$

$$\text{And } S = \frac{R}{2865} \cos^{-1}\left(\frac{R-m}{R}\right)$$



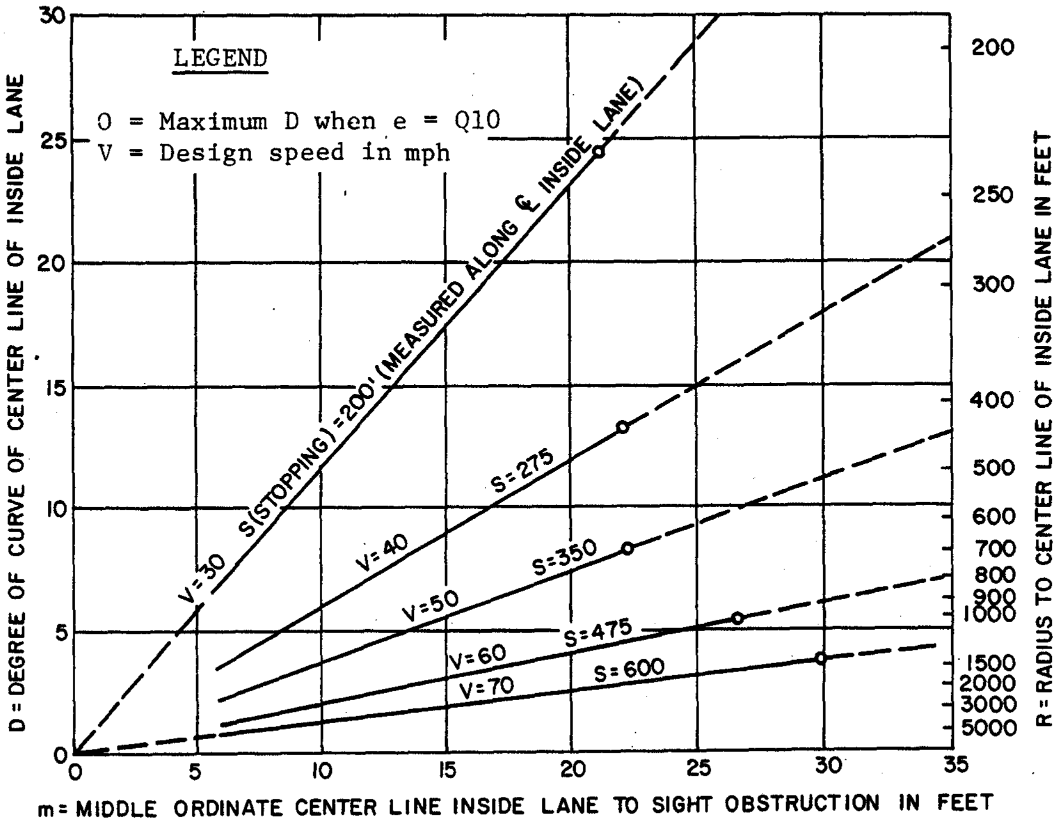


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FIGURE 3-4. STOPPING SIGHT DISTANCE ON HORIZONTAL CURVES, OPEN ROAD CONDITIONS

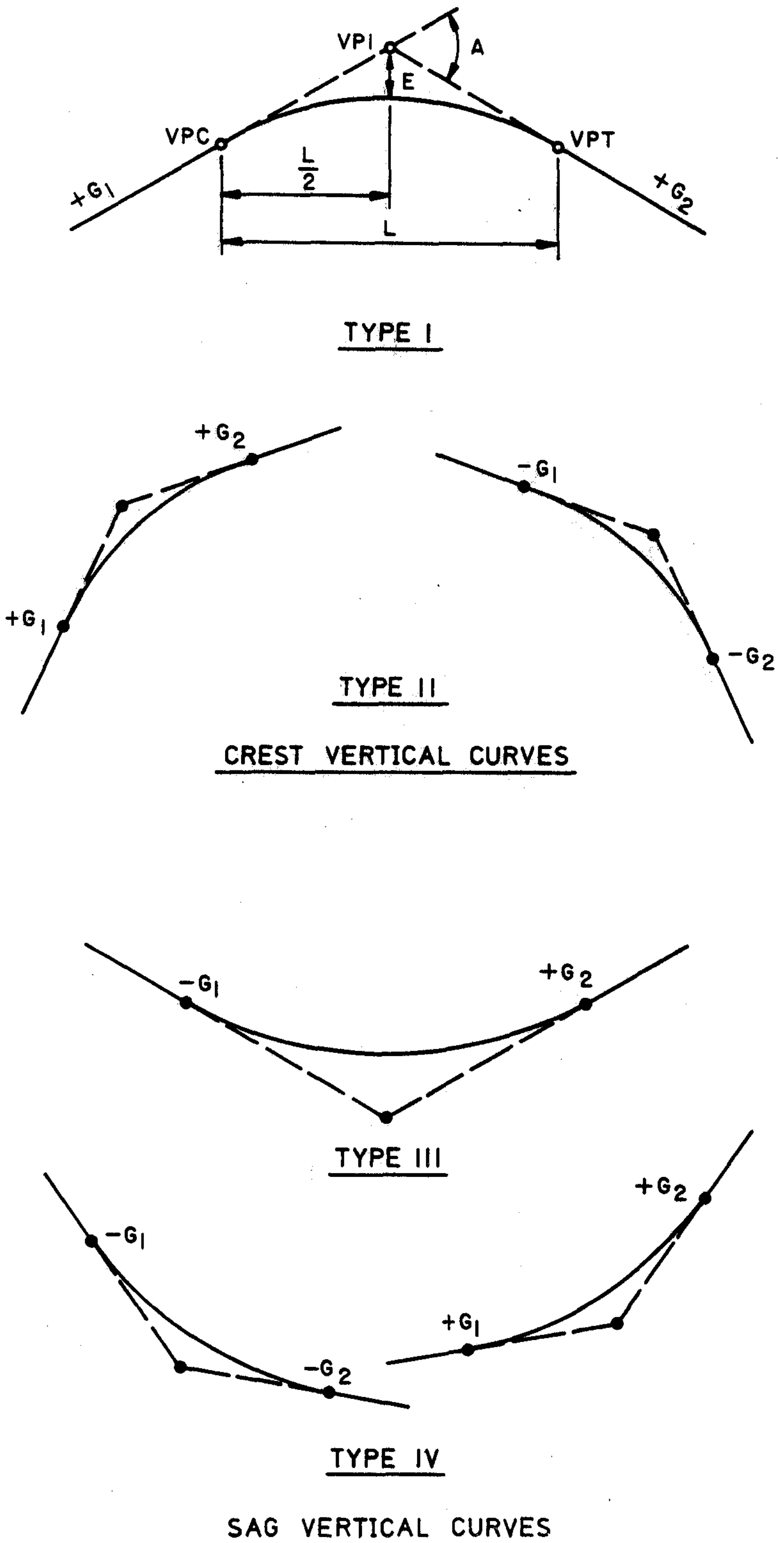

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FIGURE 3-5. TYPES OF VERTICAL CURVES

economically feasible. The minimum length of vertical curves is also shown in tables 1-1 and 1-2.

3-7. Cross section. Figures 3-6 and 3-7 illustrate typical combinations of cross-section elements for which geometric design criteria are outlined in tables 1-1 and 1-2. Other combinations of these cross-section elements are illustrated in AASHTO GU-2.

a. Roads.

(1) Normal-crown section. The typical road-type, normal-crown cross section shown in figure 3-6 comprises the so-called "streamlined" cross section. Shoulder edges, channel bottoms, and the intersection of side slopes with original ground are rounded for simplification of maintenance and appearance. On roads in open areas rounding of shoulder edges will be restricted to a strip 3 to 4 feet wide at the intersection of slopes steeper than 2-1/2:1, and only slight rounding will be used at intersections of slopes flatter than 2-1/2:1.

(2) Superelevated section. Figure 3-6 shows the preferable superelevated cross sections for roads at Army installations. The low side of this cross section is similar to a normal-crown section except that the shoulder slope on the low side of the section is the same as the pavement superelevation, except where normal slope is greater. On the high side of a superelevated section the algebraic difference in cross slopes at the pavement edge should not exceed about 0.07. The vertical curve should be at least 4 feet long, and at least the inside 2 feet of the shoulder should be held on the superelevated slope.

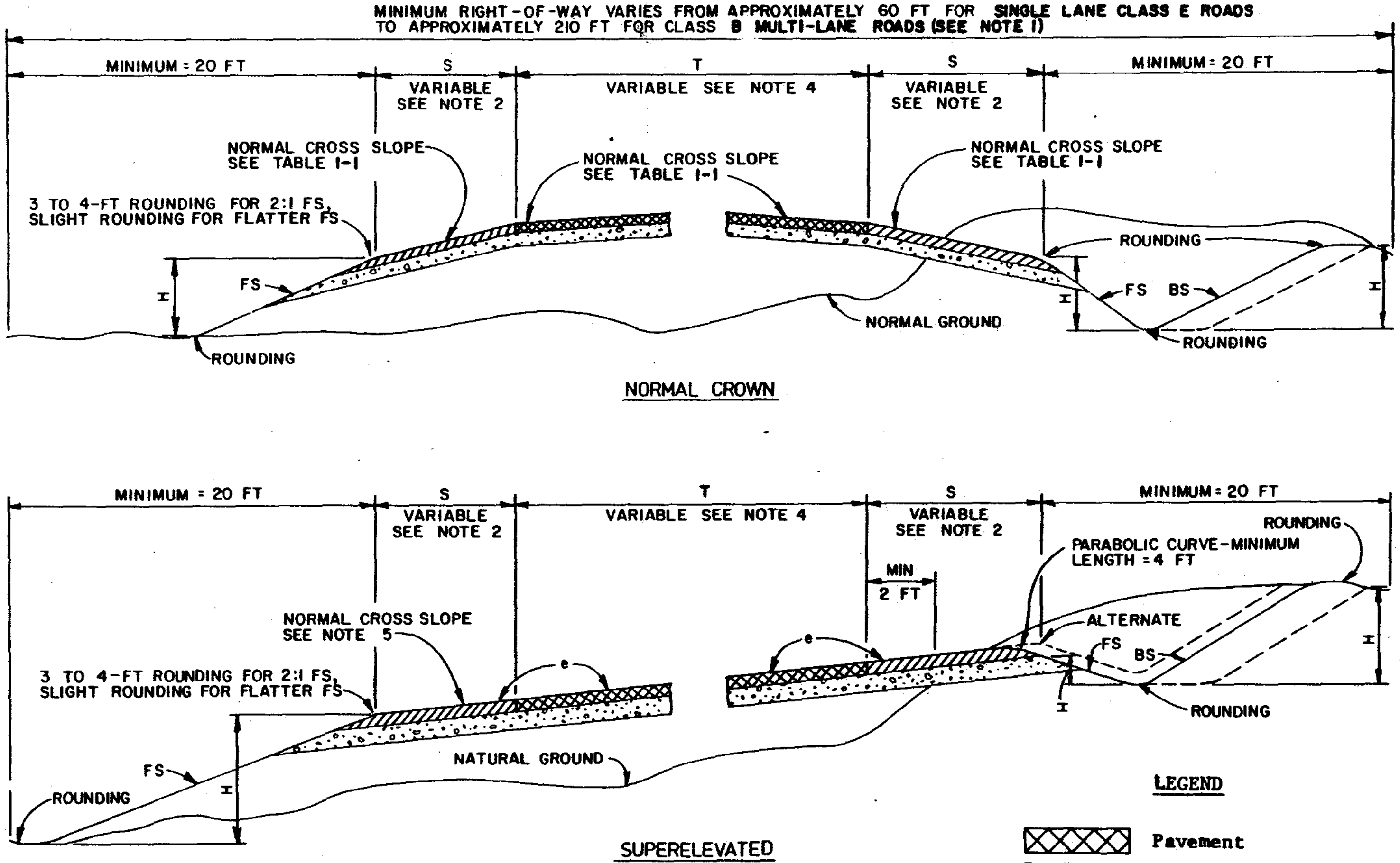
b. Streets. Typical street-type cross sections with and without parking are shown in figure 3-7. Geometric design for the various cross-section elements shown are presented in table 1-2.

3-8. Intersection criteria.

a. General. Practically all highways within Army installations will intersect at grade, and normally the designer will need to consider only plain unsignalized or signalized intersections. Intersections are normally closely spaced at regular intervals along streets in built-up areas, and the capacity of these streets will in most cases be controlled by intersection capacity.

b. Design criteria. Geometric design criteria for intersections are presented in AASHTO GD-3, GU-2, SR-2 and the TRB Highway Capacity Manual.

c. Army installation areas equivalent to design criteria areas. Variations in average intersection capacities on one-way and two-way streets subject to fixed time signal control are shown for general types of areas within cities in the TRB Highway Capacity Manual. The curves used at a particular location on Army installations should be



NOTES:

1. Variations in cross section and right-of-way are shown in AASHTO GD-2
2. The width of usable shoulders required varies with road classification, steepness of front slopes and guardrail or guidepost locations, see **table 1-1.**
3. Steepness of front and back slopes varies with H as shown in **figure 3-2.**
4. T varies with road classification. Traffic composition and type curb used in design see **table 1-1.**
5. Use superelevation rate e where greater than normal cross slope.
6. **See note 1, figure 3-2 for maximum value of H.**

LEGEND

	Pavement
	Shoulder
	Base Course
FS	**Front Slope**
BS	**Back Slope**
H	**Height of cut or fill**
S	**Width of shoulder**
T	**Total width of traffic lanes**
e	**Superelevation rate**

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FIGURE 3-6. TYPICAL ROAD-TYPE CROSS SECTIONS

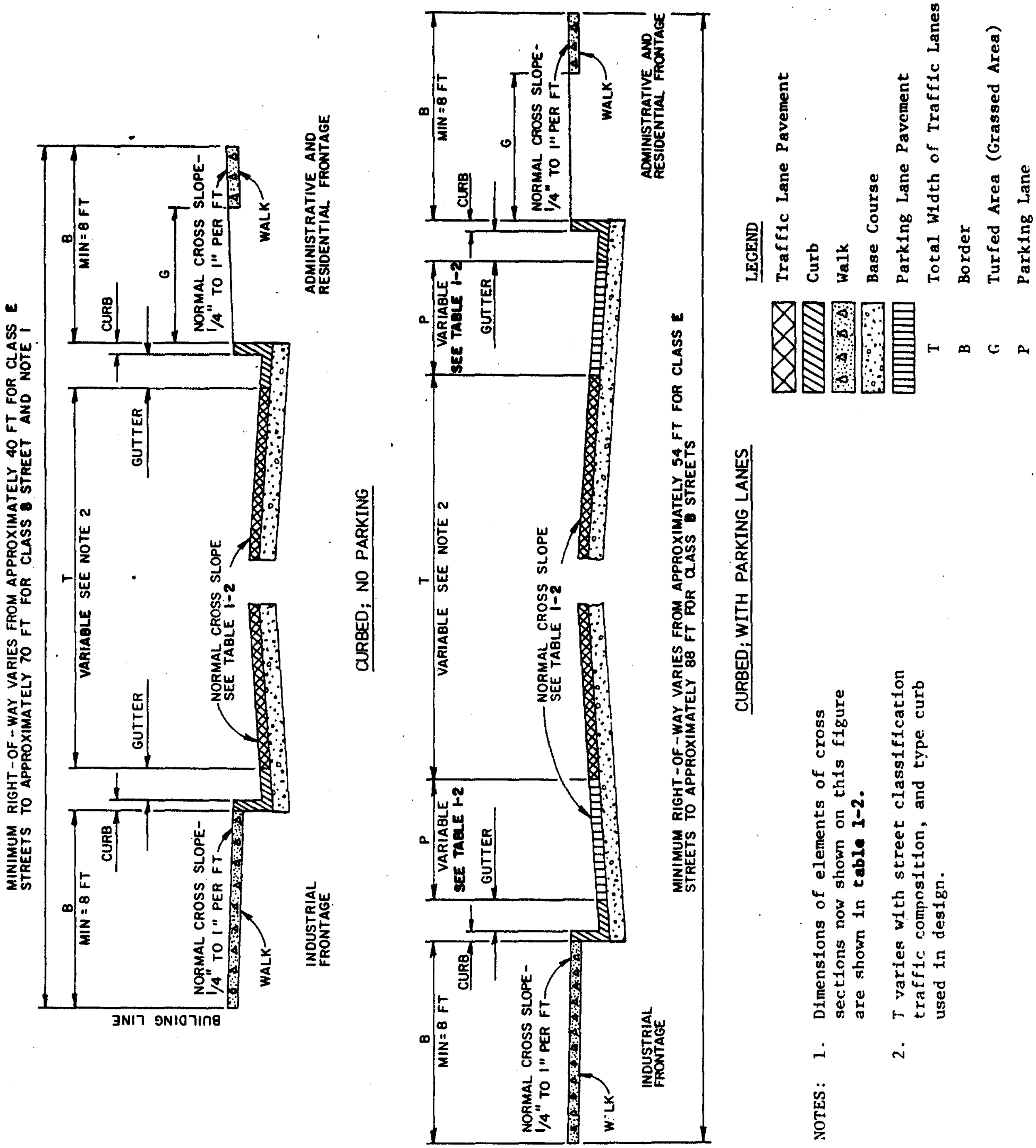

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FIGURE 3-7. TYPICAL STREET-TYPE CROSS SECTIONS selected on the basis of similarity with the type of area indicated in the TRB Highway Capacity Manual. The following tabulation indicates areas in which the intersection curves should normally be used.

Area Designation Used in Highway Capacity Manual	Equivalent Area at Army Installations
Downtown	Central portion of built-up areas at major installations
Fringe, business district	Central portion of built-up areas at all but major installations. Industrial, service, and warehouse areas at major installations.
Outlying business district and intermediate residential	Residential portion of built-up areas at major installations. Industrial, service, warehouse, and residential portions of built-up areas at intermediate installations. All built-up areas at small installations, isolated shopping centers, community centers, and similar areas of public assembly in open areas. Isolated road intersections in open areas.
Rural	TRB Highway Capacity Manual.

3-9. Capacity of intersections. The capacity (DHV) shown in tables 1-1 and 1-2 is for free-flowing highways without intersections at grade or with few crossroads and minor traffic. These highways have no traffic control signals at intersections (plain unsignalized intersections), and capacity is affected very little and uninterrupted flow is assumed. The AASHTO procedure is suggested as a guide in design of intersections.

AASHTO Suggested Design Hourly Volume Combinations for Which Signal Control Should be Assumed in Geometric Design of Intersections.

Type of Intersection	Minimum Two-Way DHV		
2-lane through highway	400	500	650
Crossroad	250	200	100
4-lane through highway	1,000	1,500	2,000
Crossroad	100	50	25

This tabulation may serve as a general guide for design of at-grade intersections in the following manner. If the DHV of traffic at a given intersection is approximately equal to or less than that shown in the tabulation, capacity of the through highway is based on the DHV shown in tables 1-1 and 1-2, and no intersection capacity analysis is required. If the DHV of traffic is greater than that shown in this tabulation, the intersection should be designed as if it were under signal control. The geometric layout should be made in conjunction with an intersection capacity analysis, as in the Highway Capacity Manual. The volumes shown in this tabulation have no relation to warrants for signalization, nor are they indicative of whether or not signalization should be used. Warrants for traffic control signals are given in ANSI D6.1.

3-10. Intersection curves.

a. Minimum edge of pavement design. Where it is necessary to provide minimum space for turning vehicles at unsignalized at-grade intersections, the AASHTO design criteria presented in GU-2 and SR-2 should be used. The minimum radius for edge of pavement design on street intersections is 30 feet, which is required for passenger (P) cars on 90-degree turns. A larger radius should be used if any truck traffic is expected or turning speeds greater than 10 mph are anticipated. The minimum radius on road intersections is 50 feet.

b. Minimum curb radii. Minimum curb radii are normally used at plain unsignalized intersections to reduce intersection area and minimize conflict between pedestrians and vehicles. The curb design should fit the minimum turning path of the critical design vehicle expected in the traffic. Generally, the minimum curb radii to be used on intersection curves may be determined on the basis of the following information.

(1) Curb radii of 15 to 25 feet are adequate for P design vehicles and should be used on Classes D and E cross streets where practically no single unit (SU) truck, WB40, WB50, and WB60 (semitrailer combination trucks) design vehicles are expected or at major intersections where parking is permitted on both intersecting streets. Radii of 25 feet should be provided on all new construction and on reconstruction where space is available.

(2) Curb radii of 30 feet or more should be provided at all major highway intersections to accommodate an occasional truck in the traffic. (See table 2-1 for minimum turning radius.)

(3) Radii of 40 feet or more, preferably three-centered compound curves, to fit the path of the critical design vehicle expected in the traffic, should be provided where SU, WB40, WB50, and WB60 design vehicles turn repeatedly. (See table 2-1 for minimum turning radius.)

3-11. Miscellaneous.

a. Signing. Signs should conform with ANSI D6.1 standards.

b. Pavement markings. Marking should be provided on paved surfaces as a safety measure and to increase orderly traffic flow. Markings should conform to local highway practice criteria. Standard requirements are provided in ANSI D6.1 on uniform traffic control devices.